

CLAIMS

What is claimed is:

1. An optical device for coupling a first optical fiber having a first cross-sectional
5 material pattern to a second optical fiber having a second cross-sectional material pattern
different than the first, comprising:
a first end adapted to connect to the first optical fiber and having a third cross-
sectional pattern substantially matched to said first cross-sectional material pattern;
a second end adapted to connect to the second optical fiber and having a fourth
10 cross-sectional pattern substantially matched to said second cross-sectional material
pattern; and
a transition region between said first and second ends, said transition region being
designed and configured such that an optical signal entering said first end from said first
optical fiber propagates adiabatically to said second end;
15 whereby reflections of the optical signal back into the first optical fiber are
avoided.
2. The optical device of claim 1, wherein said first, second, third, and fourth cross-
sectional material patterns each comprise a void pattern.
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3. The optical device of claim 1, wherein said first and third cross-sectional material
patterns each comprise a first void pattern, and wherein said second and fourth cross-
sectional material patterns each comprise a solid pattern.
- 25 4. The optical device of claim 3, said first void pattern being characterized by void
sizes, void center-to-center spacings, and a number of voids, wherein said transition region
comprises a transition sequence of void patterns that changes gradually from said first void
pattern at said first end to said solid pattern at said second end over an axial distance that is
at least ten thousand times longer than a wavelength of the optical signal.

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5. The optical device of claim 4, said transition sequence also being characterized by void sizes, void center-to-center spacings, and a number of voids, wherein the void sizes of said transition sequence remain constant over the axial distance of the transition region, while the number of voids of said transition sequence decreases gradually to zero at said
5 second end.

6. The optical device of claim 5, said first and second fibers each comprising cores, said transition region comprising a corresponding core that tapers in size from a size of said first fiber core at said first end to a size of said second fiber core at said second end.

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7. The optical device of claim 4, wherein the void sizes of said transition sequence decrease gradually to zero at said second end.

8. The optical device of claim 7, wherein said transition region core has a material
15 refractive index profile selected such that an effective refractive index of said transition region core is equal to an effective refractive index of said first fiber core at said first end, varies linearly with axial distance from said first end, and is equal to a refractive index of said second fiber core at said second end.

20 9. A microstructured optical fiber transformer element for coupling a microstructured optical fiber (MOF) to a solid optical fiber (SOF), comprising:
an MOF-matched end having a void pattern and an effective refractive index profile substantially similar to a void pattern and an effective refractive index profile of the MOF;

25 an SOF-matched end having a solid cross-section and a refractive index profile substantially similar to a refractive index profile of the SOF; and
a transition region connecting said MOF-matched end to said SOF-matched end, said transition region being designed and configured such that a light signal entering said MOF-matched end or said SOF-matched end propagates adiabatically to the other end.

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10. The microstructured optical fiber transformer element of claim 9, wherein said transition region has a longitudinal length that is at least ten thousand times a wavelength of the light signal.

5 11. The microstructured optical fiber transformer element of claim 9, said transition region comprising a core region having a size substantially similar to that of a core region of the MOF at said MOF-matched end, said core region having a size substantially similar to that of a core region of the SOF at said SOF-matched end.

10 12. The microstructured optical fiber transformer element of claim 11, said transition region comprising a cladding region having a size substantially similar to that of a cladding region of the MOF at said MOF-matched end, said cladding region having a size substantially similar to that of a cladding region of the SOF at said SOF-matched end.

15 13. The microstructured optical fiber transformer element of claim 12, said MOF void pattern being characterized by void sizes, void center-to-center spacings, and a number of voids, said transition region having a transition sequence of void patterns that incrementally changes from said MOF void pattern at said MOF-matched end to a solid cross-section at said SOF-matched end.

20 14. The microstructured optical fiber transformer element of claim 13, said transition sequence being characterized by void sizes, void center-to-center spacings, and a number of voids, wherein said void sizes remain constant over the axial distance of the transition region, while said number of voids decreases gradually to zero at said SOF-matched end.

25 15. The microstructured optical fiber transformer element of claim 13, said transition sequence being characterized by void sizes, void center-to-center spacings, and a number of voids, wherein said void sizes adiabatically decrease from said MOF void sizes at said MOF-matched end to zero at said SOF-matched end.

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16. The microstructured optical fiber transformer element of claim 13, wherein a material refractive index profile of said transition region core region varies with axial distance from said MOF-matched end such that an effective index of refraction of said transition region core region changes linearly from an effective index of refraction of said MOF core region at said MOF-matched end to an index of refraction of said SOF core region at said SOF-matched end.

17. The microstructured optical fiber transformer element of claim 15, said MOF core being larger than said SOF core, wherein said transition sequence comprises core void center-to-center spacings that correspond to said MOF core void center-to-center spacings at said MOF-matched end, decrease proportionally with distance from the MOF-matched end, and correspond to said SOF core size at said SOF-matched end.

18. The microstructured optical fiber transformer element of claim 17, wherein said transition sequence comprises cladding void center-to-center spacings that correspond to said MOF cladding void center-to-center spacings at said MOF-matched end, radially stretch with distance from the MOF-matched end to occupy an increasing cladding area, and correspond to said SOF cladding size at said SOF-matched end.

19. A method of fabricating an optical fiber, comprising:
forming a plurality of component wafers representing axially adjacent slices of a preform;
bonding said component wafers together into a preform; and
drawing the preform to create the optical fiber.

20. The method of claim 19, said bonding step yielding a bonded stack, further comprising:

attaching sacrificial end portions to each end of the bonded stack to form the preform; and

clipping extraneous ends corresponding to the sacrificial end portions from the optical fiber.

21. The method of claim 19, wherein each of the component wafers is attached to a sacrificial substrate prior to said bonding step, said bonding step comprising:

turning a second wafer over onto a first wafer;

5 bonding the second wafer to the first wafer, thereby creating a two-element bonded stack between two sacrificial layers;

removing the sacrificial layer associated with said second wafer, thereby exposing the two-element bonded stack;

turning a third wafer over onto the two-element bonded stack;

10 bonding the third wafer to the two-element bonded stack, thereby creating a three-element bonded stack between two sacrificial layers; and

removing the sacrificial layer associated with said third wafer, thereby exposing the three-element bonded stack.

22. The method of claim 19, said optical fiber being operable as a microstructured
15 optical fiber transformer element, further comprising the step of lithographically forming void patterns into consecutive component wafers.

23. The method of claim 22, wherein said step of lithographically forming void
20 patterns into consecutive component wafers is performed prior to said bonding step.

24. The method of claim 22, said bonding step yielding a bonded stack, wherein said
step of lithographically forming void patterns into consecutive component wafers is
performed after said bonding step through application of an iterative lithographic process
to said bonded stack.

25. The method of claim 22, wherein said component wafers have refractive index
profiles and void patterns that gradually vary thereamong, such that the resulting optical
fiber allows a light signal to pass through adiabatically from a first end to a second end.

30 26. The method of claim 25, wherein each of said component wafers is mechanically removed from existing preforms known to have the desired refractive index profile.

27. The method of claim 25, wherein each of said component wafers is formed by growing a layer of silica using a chemical vapor deposition process.

5 28. The method of claim 25, wherein each of said component wafers is formed by a flame hydrolysis process.

29. An optical fiber comprising:

a first end and a second end having different effective refraction indices;

10 an intermediate portion connecting the first and second ends and having an effective refractive index that changes substantially gradually and substantially adiabatically along a length of the fiber.

30. An optical fiber as in claim 29 in which the fiber comprises a core having multiple,
15 axially elongated voids therein extending along at least a part of the intermediate portion.

31. An optical fiber as in claim 30 in which the fiber has a cladding surrounding the core and having multiple, axially elongated voids therein extending along at least a part of the intermediate portion.

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32. An optical fiber as in claim 31 in which the voids in at least one of the core and cladding change along a length of the fiber to thereby change said effective refractive index.

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33. An optical fiber as in claim 32 in which the change in the voids comprises a change in cross-sectional area of the fiber occupied thereby.

34. An optical fiber as in claim 33 in which the change in cross-sectional area
5 comprises a change in a number of voids per cross-section.

35. An optical fiber as in claim 33 in which the change in cross-sectional area comprises a change in cross-sectional area of individual voids.

10 36. An optical fiber as in claim 29 in which the optical fiber has a core of a diameter that differs between the first and second ends.

37. A method of making an optical fiber comprising:
forming a core and a cladding surrounding the core;
15 said forming comprising varying selected characteristics of said fiber to cause a substantially gradual and substantially adiabatic change in effective index of refraction along a length of the fiber.

38. A method as in claim 37 in which said varying comprises causing variations in
20 axially elongated voids in at least one of said core and cladding.

39. A method as in claim 37 in which said varying comprises causing variations in axially extending voids in each of said core and cladding.

40. A method as in claim 37 in which said core has one diameter at a first end and a different diameter at a second end.

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FIG. 10